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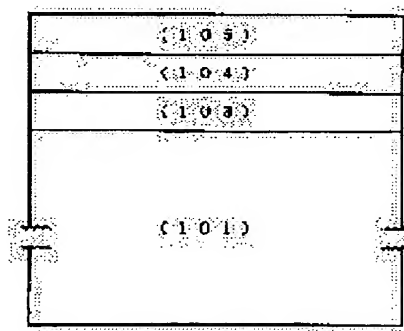
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## (54) SEMICONDUCTOR DEVICE AND FABRICATION THEREOF

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a multilayer structure including a heterojunction based emission layer on a substrate of amorphous material by depositing a III-V compound semiconductor heterojunction comprising at least one kind of group III element including Al, Ga and In and a group III-V element containing at least nitrogen directly on the substrate of amorphous material.

SOLUTION: A substrate 101 is subjected, on the surface thereof, to nitrogen plasma processing and an n-type  $\text{AlN}_{0.05}\text{P}_{0.95}$  layer is deposited directly thereon as a lower clad layer 103. Subsequently,  $\text{C}_5\text{H}_5\text{In}$  and  $\text{NH}_3$  are fed to the reaction system in order to deposit a p-type  $\text{Ga}_{0.4}\text{In}_{0.6}\text{N}$  layer as an emission layer 4. Finally, a heterojunction of the  $\text{Ga}_{0.4}\text{In}_{0.6}\text{N}$  emission layer 104 and the lower clad layer 103 of  $\text{AlN}_{0.05}\text{P}_{0.95}$  deposited directly on the surface of amorphous AlN substrate 101 is formed. The multilayer structure including a heterojunction based emission layer may be provided on a substrate of amorphous material by plasma processing of a gas containing nitrogen atoms on the surface of amorphous substrate.



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CLAIMS

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[Claim(s)]

[Claim 1] They are at least one sort of \*\* among aluminum, Ga, or In. It consists of an III group element and the Vth group element which contains nitrogen at least. Semiconductor device for light emitting devices which it comes to consist of laminated structures which deposited the III-V group nitride semi-conductor heterojunction directly on the front face of an amorphous ingredient substrate.

[Claim 2] The semiconductor device for light emitting devices according to claim 1 with which it comes to form a metal coat with the front face of the substrate which deposited the III-V group nitride semi-conductor heterojunction on the rear face of the substrate of the opposite side.

[Claim 3] The semiconductor device for light emitting devices according to claim 2 which established two or more slots in the rear face of an amorphous ingredient substrate, and prepared the metal coat on it further.

[Claim 4] They be at least one sort of \*\* among aluminum , Ga , or In to the this substrate front face after putting an amorphous ingredient substrate into the plasma ambient atmosphere containing a nitrogen atom . It consist of an III group element and the Vth group element which contain nitrogen at least . The manufacture approach of the semiconductor device for light emitting devices characterize by making an III-V group nitride semi-conductor heterojunction deposit .

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[Translation done.]

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## DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] With respect to the semiconductor device which consists of an III-V group nitride semi-conductor, it is related with the configuration of the ingredient which brings about increase of the luminescence reinforcement of the short wavelength visible light emitting diode (LED) of high brightness especially.

[0002]

[Description of the Prior Art] III-V group nitride semi-conductors, such as gallium nitride (GaN), aluminum nitride (AlN), indium nitrides (InN), or those mixed crystal, are used as a component of semiconductor devices, such as a field effect transistor (M. Appl.Phys.Lett. besides Asif Khan, 65 (9) and (1994), 1121.) of an environmental-proof mold, LED, etc. which operate also at an elevated temperature comparatively. Recently, short wavelength visible LED which emits light in the light of wavelength with short blue which consists of a laminated structure of III-V group nitride semi-conductors, such as GaN, bluish green color, etc. consists of (for example, Manabe Katsuhide, the "TOYODA GOSEI technical report", volume [ 35th ] No. 4 (1993), 68 pages).

[0003] The example of structure of the conventional LED chip which consists of III-V group nitride semi-conductors is shown in drawing 1. Nitride semi-conductor each class for constituting an LED chip is prepared on the aluminum-oxide (aluminum  $2O_3$ ) single crystal (sapphire) substrate (201) (118 (1971) for example, J.Electrochem.Soc. besides H.M.Manasevit, 1864). It has been usually from the former that the sapphire which is a single crystal is used as a substrate.

[0004] One of the reasons the sapphire which is a single crystal is used as a substrate is because sapphire penetrates the light of short wavelength, such as blue, so luminescence is not absorbed by the substrate and cannot prevent emission of luminescence to the exterior. If it is in LED, in order to take out luminescence efficiently to the exterior, it has been usually to constitute a substrate from the ingredient which has a band gap higher than the energy equivalent to luminescence wavelength.

[0005] Moreover, each class of an III-V group nitride semi-conductor which is GaN which is the component of the conventional LED, AlN(s), or those mixed crystal is growing at about 1000-degree C elevated temperature (M. Illegems, J.Cryst.Growth, 13/14 (1972), 360.). Generally such an elevated temperature is needed for growth of an III-V group nitride semi-conductor layer irrespective of growth methods, such as vapor growth (VPE law) which uses metal-organic chemical vapor deposition (called MOCVD, MOVPE, and the OMVPE method.) and a halogenide as a raw material. Therefore, the existing heat-resistant ingredient with the high melting point which does not deteriorate at hot growth temperature, either needed to be used as the substrate. The reason for using as a substrate about 2040-degree C sapphire with which the melting point exceeds growth temperature is here.

[0006] as a substrate -- in addition to this -- the oxidization gallium neodium ( $NdGaO_3$ ) (collection No[ of the 55th time Japan Society of Applied Physics academic lecture meeting lecture drafts of the 1994 autumn ]. 1, - 4,184 page of lecture number 19 p-MG) of a single crystal -- similarly the zinc oxide ( $ZnO$ ) of a single crystal is used. Since 3.2eV and a band gap penetrate without absorbing the light of short wavelength widely, and since whenever [ mismatching / of a grid with III-V group nitride semi-conductor mixed-crystal ingredients, such as  $AlGaInN$  ] is small, the band gap of  $ZnO$  is indicated as a substrate suitable for growth of an III-V group nitride semi-conductor (JP,6-14564,B).

[0007] As for the conventional substrate ingredient for III-V group nitride semi-conductor layer growth, a single crystal ingredient is used in many cases. Generally single crystals, such as sapphire, are compounded under the environment in elevated-temperature high pressure by using the powder of an alumina, or the sapphire lump of polycrystal as a raw material. After passing through a single crystal composition process, cutting is carried out to a desired configuration. Then, a precision grinds a front face mechanically or chemically, and it is offered as a substrate. That is, it must pass through many processes to obtain the ingredient of the single crystal used as a substrate, therefore, generally the single crystal ingredient is expensive.

[0008] The general reason for using a single crystal ingredient as a substrate is for obtaining the growth phase of a single crystal. That is, it is because the growth phase which carried out epitaxial (epitaxial) growth on the single crystal substrate serves as a single crystal. Since the single crystal growth phase is built from the crystal face of the same bearing, it is convenient for obtaining components, such as LED to which the optical

or electric property was uniformized and the property was equal. Rather, it is required that LED should consist of film of a single crystal.

[0009] However, if it is in III-V group nitride semi-conductors, such as AlN, it crystallizes, even when it is made to grow up on the ingredient which is not a single crystal, and it is known that the single crystal film will be obtained (the Akasaki \*\*\*\* "optics", volume [ 22nd ] No. 11 (1993), 670 pages). It means that an expensive single crystal substrate does not generally have to be needed for this obtaining the III-V group nitride semi-conductor film of a single crystal. That is, if a single crystal composition process is not required for single-crystal-izing but it generally compares with the ingredient of a single crystal, it will have suggested that an amorphous ingredient without cheap crystallinity can be used.

[0010] If it was in the past, Pyrex glass is used as an amorphous ingredient and the example in which the monolayer of AlN which is a kind of an III-V group nitride semi-conductor was formed on it is known ("application physics" besides Kamimura \*\* 1 \*\* volume [ 40th ] No. 5 (1971), 572 pages). Moreover, there is an example which also prepared the AlN film on the electrode which consists of a conductive glass ingredient (G. Phys.Rev. besides A.WOLFF, 114 (5) and (1959), 1262.). However, in the example in the former, although  $\text{Al}_x\text{Ga}_{1-x}\text{N}$  ( $x$ , and  $y$  and  $z$  express a presentation ratio, and are  $x+y+z=1$  and  $x>0$ ) is shown as an ingredient which emits light in the light of short wavelength (JP,6-14564,B), the embodiment which prepares directly the heterojunction laminated structure of the LED application equipped with the mixed-crystal layer etc. as a luminous layer on an amorphous ingredient is not illustrated.

[0011] If it is the ingredient which penetrates the light of short wavelength even when using an amorphous ingredient as a substrate, luminescence can be efficiently taken out to the exterior and increase of luminescence reinforcement can be achieved. If the metal coat which has the function to reflect in one principal plane of the ingredient of translucency luminescence which penetrates a substrate ingredient is prepared, it does not depend on the crystalline improvement in an epitaxial film, but \*\* can also attain high brightness-ization of still much more LED simple. Moreover, high brightness-ization can be attained more by constituting a part for a light-emitting part from a heterojunction.

[0012] After using an amorphous ingredient as quartz glass and forming the metal electric conduction film on the 1 principal plane of quartz glass, the growth approach which deposits  $\text{Al}_w\text{Ga}_{1-w}\text{N}$  ( $0\leq w\leq 1$ ) and an InN epitaxial film is also learned. In this case, an III-V group nitride semi-conductor layer is not directly deposited on quartz glass. On front faces, such as quartz glass which gave optical polish, once Chromium (Cr), nickel (nickel), Metals, such as molybdenum (Mo), gold (Au), or platinum (Pt), are made to put as electric conduction film, conductivity is given to front faces, such as quartz glass, and the III-V group nitride semi-conductor layer is grown up the appropriate back (JP,5-86646,B). However, the heterojunction is not included in this case. Moreover, this growth approach is exactly an approach made advantageous to therefore producing the light emitting device of high brightness with the crystalline improvement in an epitaxial film for the purpose of growth of  $\text{Al}_x\text{Ga}_{1-x}\text{N}$  ( $0\leq x\leq 1$ ) of high quality with few nitrogen vacancies, or the epitaxial film of InN forming a growth phase through the metal electric conduction film formed on the surface of quartz glass. That is, no conductive film prepared on the surface of quartz glass was prepared in order to achieve the operation as reflective film for reflecting luminescence.

[0013] Furthermore, it faces growing up an III-V group compound semiconductor layer through the metal electric conduction film prepared on the quartz glass by the well-known example, direct current voltage is impressed between the metal electric conduction film and target ingredients, such as metal aluminum, and the buffer layer of  $\text{Al}_x\text{Ga}_{1-x}\text{N}$  ( $0\leq x\leq 1$ ) or InN is first deposited by the RF-sputtering method in the ambient atmosphere containing nitrogen gas. then, ammonia (NH<sub>3</sub>) the — III Epitaxial growth of  $\text{Al}_x\text{Ga}_{1-x}\text{N}$  ( $0\leq x\leq 1$ ) of the same presentation as a buffer layer or the InN is carried out by the metal-organic chemical vapor deposition which uses a group's organic metal as a raw material (JP,5-86646,B). If it depends on this growth approach,  $\text{Al}_x\text{Ga}_{1-x}\text{N}$  ( $0\leq x\leq 1$ ) of high quality with few nitrogen vacancies and the epitaxial film of InN are obtained, and if spread, although there is an advantage which can produce the light emitting device of high brightness, the complicated process is needed for obtaining an epitaxial film. For example, even if it makes it the growth process of an epitaxial film, it becomes indispensable and a growth process becomes complicated, and since it is complicated, the sputtering method, metal-organic chemical vapor deposition, and two sorts of growth approaches may cause the rise of the manufacture price of a light emitting device.

[0014] For example, if it is in an unspecified device like LED, since a cheap thing is required especially, a complicated process is not desirable. If it is in the substrate which consists of an amorphous ingredient, even if it grows up a direct III-V group nitride semi-conductor layer on a substrate, the single crystal film is not obtained easily. The simple surface treatment which can promote single crystal-ization of the growth phase deposited on it is required for one principal plane of the amorphous ingredient which deposits an III-V group nitride semi-conductor layer, i.e., the front face of a substrate.

[0015] High brightness-ization of a light emitting device has the configuration which has the function to reflect not only quality improvement of the epitaxial growth film but luminescence, then the case where high brightness-ization is attained simply. For example, the conventional method which arranges a reflecting mirror in a suitable location and promotes emission of luminescence to the exterior is known. The example of a configuration of the conventional LED which comes to have such a reflecting mirror is shown in drawing 2. The reflecting mirror (111) which brings about high brightness-ization is conventionally formed in a part of stem (plinth instrument) (113) for fixing the chip (112) of LED. In the former, it was special for reflecting

luminescence in this appearance, and the stem from which structure becomes complicated was needed. For example, simplification of structure can be attained, if a substrate is translucency and the member aiming at obtaining reflex action to some substrates will be put using it. however, the member for the purpose which acquires the operation which reflects luminescence for achieving high brightness-ization in this appearance by current — having — in addition — and LED of high brightness which consists of a simplified configuration is not known.

[0016] For example, unlike the well-known example shown in drawing 2, with the front face which deposits the III-V group nitride semi-conductor layer of the quartz-glass substrate which is translucency, if the metallic reflection film is prepared in an one principal plane [ of the opposite side ], i.e., rear face of substrate, side, the reflectivity to the exterior of LED of luminescence can be increased. If processing to which the surface area of the rear face of a substrate in which the reflective film is prepared is expanded is performed, since reflectivity increases with the escape of the surface area of the reflective film which has reflex action, it will increase further. The approach of forming a concave convex slot in a front face is in one of the processing approaches which brings about the increment in surface area. The method of growing up the crystal layer of the same hexagonal system as a substrate is also exhibited on the substrate of the hexagonal system which actually has the field (0001) which formed the slot in the front-face side (JP,5-36602,A). However, conventionally, the slot is formed in the front-face side of a hexagonal substrate, and a slot is prepared again in order to raise the surface state of the film of the hexagonal form of the same crystal system as a substrate, and in order to make the surface area of one principal plane of a substrate extend, the slot is not prepared.

[0017]

[Problem(s) to be Solved by the Invention] In order to supply cheap LED, a best policy uses an amorphous ingredient as a substrate. Surface treatment which gives the single crystal film easily on an amorphous substrate front face is required for it. Furthermore, it is still more convenient if there is a simple configuration to which the member which has the operation which reflects luminescence, without needing a special stem contacts a substrate, and is prepared, the reflectivity of luminescence from LED is increased, and increase of the luminescence reinforcement from LED is brought as a result. However, pn junction required [ by the time it results in current, there is little power consumption about visible LED of short wavelength, and ] to obtain the high brightness LED, and the example in which the laminated structure containing the heterojunction system luminous layer to make was prepared on the amorphous ingredient substrate are not known. Or the example in which the configuration which brings about increase of the reflectivity of luminescence was prepared on the amorphous substrate is not known. In order to supply cheap LED of high brightness in view of such a background, it is the technical problem of this invention to have a new original idea and to solve these conventional problems.

[0018]

[Means for Solving the Problem] that is, this invention be at least one \*\* of aluminum and Ga after putting and carrying out surface treatment of the substrate which consist of an amorphous ingredient to the plasma ambient atmosphere of the gas containing a nitrogen atom, or In. it be characterize by depositing directly the laminated structure equipped with the heterojunction of the III-V group nitride semi-conductor which contain nitrogen at least as an III group element and the Vth group element on the front face of this amorphous ingredient substrate. Moreover, with the front face of the amorphous substrate which deposits an III-V group nitride semi-conductor directly, it is characterized by offering the semiconductor device with which it comes to form a metal coat on the rear face of the substrate with which the opposite side counters. A metal coat also offers the semiconductor device formed on the rear face of the amorphous substrate which prepared two or more slots.

[0019] In this invention, if it compares with a single crystal ingredient, the ingredient which is a cheap amorphous ingredient and has translucency will be used as a substrate. An amorphous ingredient points out crystallographically that it is formless (amorphous) or the ingredient which has micell (miscel) structure with the field crystallized partially. It is amorphous and amorphous glass, glass ceramics, quartz glass, etc. are mentioned to the ingredient of translucency. In addition, ceramic ingredients, such as AlN which has translucency, also correspond to this. Since membrane formation temperature, such as GaN and AlN, is generally about 1000 degrees C and an elevated temperature, the substrate ingredient which is equal to practical use, without softening or dissolving also at such an elevated temperature is desirable. If it carries out from this point, translucency ceramic ingredients, such as quartz glass and AlN, are more convenient than the amorphous glass ingredient which causes softening at low temperature comparatively. Especially since a quartz-glass ingredient has the permeability which was excellent also to short wave Nagamitsu of an ultraviolet-rays field, it is convenient.

[0020] In this invention, it puts to the plasma ambient atmosphere which consists of a gas containing the molecule which sets a nitrogen atom to one of the configuration atoms for one principal plane which deposits the growth phase of amorphous substrate ingredients, such as a quartz-glass substrate, for example, i.e., a front face, at least, and surface treatment is performed. A nitrogen atom can be made to exist in the front face of an amorphous substrate by this plasma treatment. The nitrogen atom which will exist near the substrate front face will work as a site (site) of nitrogen, if it sees from the field of a crystal growth device in case an III-V group nitride semi-conductor layer grows on a front face, and it has the effectiveness which makes growth of the single crystal film easy by this.

[0021] From the result which this invention persons examined wholeheartedly, nitrogen gas is used as a molecule which sets a nitrogen atom to one of the configuration atoms at least. If nitrogen gas is excited with the microwave whose frequency is 2.45GHz and the front face of a quartz-glass substrate is processed for 10 minutes in the vacuum environment of 80Torr(s) For example, it becomes sufficient plasma surface treatment to obtain the GaN film by which the surface section was single-crystal-ized at the growth temperature of 600 degrees C by the MOCVD method of ordinary pressure.

[0022] The plasma which processes a substrate front face may be generated using the compound containing the amine radical which is a substituent containing complex [ , such as a pyrrole (Pyrrole) which is not made to restrict for generating from nitrogen gas, for example, contains ammonia (NH<sub>3</sub>), aliphatic series, alicyclic or aromatic amine and a nitrogen atom as a component of at least one ring, ] (heterocycle type), or nitrogen, the compound containing azo (-N=N-), etc.

[0023] There is also a method of injecting for example, nitrogen ion into a substrate front face as an art on the front face of a substrate in addition to the approach of using the plasma, however, the acceleration energy which exceeds about 300 KeV(s) about nitrogen ion in order to acquire the effectiveness about the same single-crystal-izing as plasma treatment from the result to which this invention persons repeated examination -- needing -- in addition -- and the great amount exceeding 1014 to 1015cm<sup>-2</sup> or it of douse (dose) is needed. Since time amount will increase [ which comes to finish impregnation ] if a dose increases, it becomes impossible to become the simple surface treatment approach.

[0024] At least one III of aluminum, Ga, or In grown up on the amorphous substrate which this invention says There are GaN, AlN, InN, AlGaIn, GaInN, AlInN, AlGaInN, etc. in the example of the III-V group nitride semi-conductor containing a group element and nitrogen.

[0025] Moreover, as the Vth group element added to N, an III-V group nitride semi-conductor including an arsenic (symbol of element: As) or Lynn (symbol of element :P) also corresponds to this invention. There are GaNAs, GaNP, AlNAs, AlNP, InNAs, InNP, AlGaNAs, AlGaNP, GaInNAs, GaInNP, AlInNAs, AlInNP, AlGaInNAs, AlGaInNP, GaNPAs, AlNPAs, InNPAs, AlGaInNPAs, etc. in this.

[0026] In this invention, it is amorphous and the direct laminating of the heterojunction laminated structure which consists of combination of these III-V group nitride semi-conductor layers is carried out on the front face of the substrate which consists of an ingredient for which the above-mentioned plasma treatment was performed, and which penetrates the light of short wavelength. Even if it deposits a laminated structure directly on a substrate unlike the conventional example, the single crystal film can be obtained. It is because that the single crystal film can be obtained performed the above-mentioned plasma treatment to the substrate front face. There is an advantage which can skip the complicated growth process which was required to grow up AlGaIn or an InN epitaxial film on amorphous quartz glass or glass like the former from this.

[0027] There is especially no limit in the growth approach at the time of depositing an III-V group nitride semi-conductor layer directly on an amorphous substrate. A conventional MOCVD grown method and a conventional VPE grown method can be used. moreover, a molecular beam -- epitaxial (MBE) -- law and a chemistry beam -- epitaxial (CBE) -- the growth approaches, such as law, can also be performed. Either can be used although methods, such as the gas source (GS) MBE and an organic metal (MO) MBE, are therefore in the gestalt of the raw material used for the MBE method. There is no limit also about Ga, aluminum or In in growing up an III-V group nitride semi-conductor layer, or N raw material. Since it has not targeted for this invention to achieve increase of luminescence reinforcement by quality improvement of the membraneous quality by reduction of the vacant lattice defect of the nitrogen of an III-V group nitride semi-conductor layer established on an amorphous substrate, two or more growth approaches are not needed like the conventional example, but it faces obtaining the laminated structure for therefore producing a semiconductor device, and simplification of a process is attained.

[0028] A heterojunction can be formed, if the semi-conductor of a different kind (hetero) which differs in the layer which differs in the presentation of a configuration element, i.e., a configuration element, and a presentation is mutually joined out of the example of the above mentioned III-V group nitride semi-conductor even if the layer or configuration element which differs in a configuration element is the same. For example, the heterojunction of GaInN and GaInNP is an example of a heterojunction which consists of a semi-conductor layer which differs in a configuration element. InN1-v Asv which differs in the value showing a presentation ratio of v and w InN1-w Asw Junction is the example of the heterojunction which differs in a presentation ratio.

[0029] If the layer which constitutes a heterojunction is 2, the number of junction interfaces (heterojunction interface) is one. This is called a single (single) heterojunction. If the heterojunction consists of three layers, the number of heterojunction interfaces will be set to 2, and will be called a duplex (double) heterojunction. Although it may be called the Mie (triple) heterojunction if the number of heterojunction interfaces is 3, generally it is called a multiplex heterojunction. If these singles, a double heterojunction, and a multiplex heterojunction are included in a laminated structure, the laminated structure equipped with the heterojunction which this invention says will be formed.

[0030] In this invention, the coat of the metal for reflecting luminescence on the 1 principal plane of the amorphous substrate of light transmission nature is prepared. Preparing a metal coat prepares on not one principal plane that deposits an III-V group nitride semi-conductor layer, i.e., the front face of a substrate, but the rear face of a substrate. This coat for reflection can be formed if metals, such as gold (symbol of element:

Au), aluminum (symbol of element: aluminum), and chromium (symbol of element: Cr), are made to put on the rear-face side of a substrate with a vacuum deposition method. aluminum is most suitable when the economical efficiency for obtaining the height and cheap LED of a reflection factor to luminescence of a short wavelength field etc. is taken into consideration. Even if the metal coat to prepare may be the film which consists of a simple substance, for example, the film which consists only of aluminum, and is film of two-layer structure on which each class of aluminum and titanium (symbol of element: Ti) was put, for example, it is not cared about. When preparing a monolayer or the metal coat of several layers, there is especially no limit in the thickness of each class, but since about 1 to 10nm and the probability which light will penetrate if extremely thin also become high, it is not desirable. 100 to 5000nm thickness is suitable practically. For example, aluminum thin film which has the thickness designed in order to raise the reflection factor of the light of a certain specific wavelength, and Ti thin film are not cared about as the so-called optical interference membrane structure which carried out the laminating to the multilayer. If the metal coat which gives reflex action to one principal plane of a substrate ingredient is prepared, like the conventional example, it is not necessary to prepare a reflecting mirror in a stem separately, luminescence of LED can be reflected in the exterior with a simple configuration, and, therefore, increase of the luminescence reinforcement from LED will be brought about. of course, the rear-face side of the substrate concerning this invention to the stem equipped with the reflecting mirror of luminescence like the former — reflection — public funds — it does not matter in that the increment in luminescence reinforcement is achieved even if it mounts the component equipped with the group coat.

[0031] The reinforcement of the reflected light increases, so that the area which functions as a reflector is large. Especially in this invention, when preparing the metal coat for reflection in the rear-face side of a substrate although it has conductivity therefore, a slot is formed in the rear-face side of a substrate, the surface area of a substrate is expanded, and increase of a reflector product is achieved.

[0032] If a slot uses the patterning technique by the photolithography method well-known about the rear face of a substrate and it depends on the etching method etc., it can be formed. For example, the rear face of an amorphous electrically-conductive-glass ingredient is once covered with the usual photoresist ingredient. Patterning is carried out to the configuration of a wanting [ the appropriate back, expose, expose a photoresist ingredient and ] slot. Resist exfoliation liquid etc. removes the photoresist ingredient equivalent to the part of a slot, and the field of a substrate ingredient is made to expose. It etches by restricting to the field made to expose, and some substrate ingredients are removed. If the photoresist ingredient which finally remains is exfoliated, the substrate ingredient with which the slot was formed can be obtained. A slot can be formed also by mechanical cutting using machine tools, such as an engine lathe.

[0033] In order to expand surface area more, it is good to form a slot in the shape of a grid. Although the configuration of the cross section of a slot does not have limitation, if a cross section is made into the shape of a semicircle and a metallic reflection coat is prepared there, luminescence can be mostly reflected in an omnidirection. Moreover, a substrate ingredient is etched that a grid-like slot should be formed in the rear face of a substrate, and it faces removing, and if the etching drugs or the etching conditions of giving a triangle-like cross section are chosen, it will \*\*\*\* in the shape of a triangular pyramid as a result, and expansion of surface area will be brought about. There is no special limit about the quantity of the slot established in a substrate. However, since one side is a 300 to 450 micrometers rectangle, as for the common chip of LED, it is desirable that several [ at least ] slots are arranged in the configuration of this chip.

[0034] What is necessary is just to form the metal coat used as the reflective film with the function to reflect luminescence, after forming the above slots. A vacuum deposition method and the applying method can be used as the formation approach of a metal coat. By the applying method, the liquefied matter containing a metal powder or a compound etc. for which it asks, for example is applied to the field of the substrate in which the slot was formed, and the appropriate back, if it is made to heat and solidify, a metaled coat can be formed. Moreover, there is an advantage from which it is convenient for the level difference of a slot etc. being filled up with the applying method in order to use the liquefied matter, and the metal coat of a front face flat as a result is easy to be obtained. It may not be easy to obtain the coat of the thickness exceeding dozens of micrometers by the physical depositing methods, such as a vacuum deposition method and the sputtering method. in such a case, the side face of a slot — a wall surface — overall — wrap extent — once — a coat — carrying out — the coat top — after [ appropriate ] — plating (plating) — the thickness of a coat is made to increase by law etc. and there is also a means which fills a slot. However, a slot is perfectly filled with the ingredient which constitutes a metal coat, and there is no absolute need of daring carry out flattening of the substrate rear face, and it may make the configuration of a slot remain intentionally. It is because the increment in the touch area to the component of the adhesion fixative for fixing a component to a stem ingredient is caused and stubborn immobilization can be attained, if the slot which left the level difference on the irregularity imperfectly filled with the ingredient which constitutes a metal coat in a substrate rear-face side exists.

[0035] Since the depth of flute prepared in a substrate is followed on making a slot deep and the surface area of a substrate tends to be expanded, increase of the reflectivity of luminescence is caused so that a slot is made deep, but in order that a substrate may carry out lamination to coincidence, the mechanical strength of a substrate is spoiled. Therefore, as for the depth of flute prepared in a substrate, it is desirable to also stop the deepest to about 80% to the thickness of a substrate. For example, about the substrate whose thickness is



300 micrometers, the depth of flute is good to stop to 240 micrometers at the maximum.

[0036]

[Function] The plasma treatment which consists of a gas containing the nitrogen atom of an amorphous substrate front face brings about easy formation of the single crystal III-V group nitride semi-conductor layer to this front-face top, and avoids the complicatedness of an epitaxial film growth process to up to the conventional amorphous substrate. The metal coat formed in the substrate rear face increases reflection to the exterior of luminescence. The slot established in a substrate rear face extends the surface area of the metal coat which reflects luminescence, and makes reflectivity increase further.

[0037]

[Example]

(Example 1) the laminated structure of the semiconductor device application concerning this invention — MOCVD — this invention is explained to a detail based on the example acquired by law. Drawing 3 is the cross section of the laminated structure concerning this example. The insulating amorphous substance AlN was used for the substrate (101). This AlN had translucency. The thickness of a substrate (101) was about 300 micrometers.

[0038] the inside of the chamber after laying a substrate (101) in the vacuum chamber of a commercial dry etching system — a degree of vacuum — about — it exhausted until it reached  $2 \times 10^{-5}$  Torr. When the ultimate vacuum was stabilized mostly, nitrogen gas with a purity of 5 Ns was introduced in the chamber, and the pressure in a chamber was set to about 100 Torr(s). In the appropriate back, the high frequency bias whose frequency is 13.56MHz was impressed to the parallel flat electrode in a chamber, and the nitrogen plasma was generated. The above-mentioned substrate (101) was laid on the electrode of the side by which the parallel flat electrode arranged in parallel is grounded. Processing by the nitrogen plasma was performed to the front face of a substrate (101) by the nitrogen plasma generated by parallel flat-surface inter-electrode.

[0039] On the AlN substrate (101) which processed the front face by the nitrogen plasma, the AlN<sub>0.05</sub>P<sub>0.95</sub> layer of a direct n form was deposited as a lower cladding layer (103). Thickness was about 0.1 micrometers. Carrier concentration was set to abbreviation  $1 \times 10^{18} \text{cm}^{-3}$ . the ordinary pressure MOCVD according [ this layer (103) ] to trimethylgallium (CH<sub>3</sub>) (3 Ga) / trimethylaluminum (CH<sub>3</sub>) (3 aluminum) / phosphine (PH<sub>3</sub>) / hydrogen (H<sub>2</sub>) system of reaction — it was made to grow up at the temperature of 750 degrees C by law Next, PH<sub>3</sub> PH<sub>3</sub> diluted with high grade hydrogen so that it might become 10% about volume concentration H<sub>2</sub> Supply to the MOCVD system of reaction of mixed gas and 3 (CH<sub>3</sub>) Ga is suspended. A cyclopentadienyl indium (C<sub>5</sub> H<sub>5</sub> In) and ammonia (NH<sub>3</sub>) were instead supplied to the system of reaction, and the Ga<sub>0.4</sub> In<sub>0.6</sub> N layer of p form was deposited as a luminous layer (104). It is NH<sub>3</sub> as C<sub>5</sub> H<sub>5</sub> In held in temperature of 70 degrees C. The addition flow rate into the system of reaction was respectively set as a part for 170 ccpart [ for / ] and 1lcc/. Thickness could be about 0.1 micrometers. Carrier concentration was set to abbreviation  $1 \times 10^{17} \text{cm}^{-3}$ .

[0040] The heterojunction with the luminous layer (104) which consists of the lower cladding layer (103) and Ga<sub>0.4</sub> In<sub>0.6</sub> N which consist of AlN<sub>0.05</sub>P<sub>0.95</sub> directly deposited on the front face of the substrate (101) which consists of amorphous AlN in which surface treatment was carried out by the nitrogen plasma by this, without minding a metal coat like the former was formed. the diffraction pattern according [ the growth phase (103) (and (104)) deposited on the substrate (101) front face processed by the nitrogen plasma ] to the usual X-ray diffraction method showed that it was the film single-crystal-ized by each.

[0041] Next, the laminating of the up cladding layer (105) which consists of GaN<sub>0.98</sub>As<sub>0.02</sub> of p form on a luminous layer (104) was carried out. Thickness set to 0.3 micrometers and carrier concentration was set to abbreviation  $2 \times 10^{18} \text{cm}^{-3}$ . The mixed gas of the arsine (10% of volume concentration)-high grade hydrogen (90% of volume concentration) by which hydrogen dilution was carried out as a source of As was used. 3(CH<sub>3</sub>) Ga made into the source of Ga was held in temperature of 0 degree C with the thermostat, and was supplied to the system of reaction with the flow rate of 30 cc/m. The arsine (AsH<sub>3</sub>) was made into 35 cc flow rate for /.

[0042] The laminated structure of the LED application equipped with the double heterojunction which consists of a heterojunction of the heterojunction of AlN<sub>0.05</sub>P<sub>0.95</sub> layer (103) and a Ga<sub>0.4</sub> In<sub>0.6</sub> N layer (104), a Ga<sub>0.4</sub> In<sub>0.6</sub> N layer (104), and GaN<sub>0.98</sub>As<sub>0.02</sub> (105) by the above configuration was constituted by depositing directly on an amorphous AlN substrate (101). Short wavelength LED was created using this double heterojunction laminated structure. Blue luminescence on which this LED wore the bluish green color was observed, and the luminescence wavelength of that core was about 4720Å (Å). In the comparison with the conventional example about luminescence reinforcement, it was admitted that LED concerning this example gave the reinforcement which is not inferiority with the conventional LED. Here, the conventional LED points out LED which brings about luminescence of the dark green color which makes a luminous layer GaInN whose presentation ratio of In is about 0.2 which added impurities, such as cadmium (Cd) and zinc (Zn). On the other hand, the half-value width of an emission spectrum was about 340Å (Å), and when comparing with the above-mentioned conventional LED about this, it became 2 (the half-value width of the emission spectrum in the conventional LED is about 700Å.), and the thing by which an improvement remarkable according to a rank is attained about 1/. As a cause which half-value width reduced, it was judged as what reduction of the hole (vacancy) concentration of the nitrogen in the heterojunction layer deposited on it was brought by this invention by using the substrate which carried out nitrogen plasma treatment of the front face.

[0043] (Example 2) The total content of alkaline metals, such as sodium, a potassium, and a lithium, used the



amorphous quartz glass below the 5 weight ppm as a substrate (101). The cross section which meets drawing 4 in the mimetic diagram of the structure of LED concerning this example at broken-line A-A' of drawing 4 at drawing 5 is shown. The approach given [ the front face of a quartz-glass substrate (101) ] in an example 1 was followed, and surface treatment by the nitrogen plasma was performed. Although conditions, such as a degree of vacuum at the time of plasma treatment, are almost the same as an example 1, the power at the time of plasma production made it increase with 210W. Although amorphous AlN used as a substrate in the example 1 contains the nitrogen atom as a configuration element primarily, since quartz glass used a silicon dioxide (SiO<sub>2</sub>) as a principal component and did not contain a nitrogen atom as a configuration element, in order to form the site of nitrogen in the front face of a quartz-glass substrate efficiently, it increased plasma power.

[0044] the above-mentioned ordinary pressure MOCVD direct on the front face of the quartz-glass substrate (101) which performed plasma treatment — the GaN layer of n form was deposited as a lower cladding layer (103) by law. Thickness could be about 0.1 micrometers. Carrier concentration was set to abbreviation  $1 \times 10^{18} \text{cm}^{-3}$ . Next, the Ga<sub>0.88</sub>In<sub>0.12</sub>N layer of p form was deposited as a luminous layer (104). The thickness of a luminous layer (104) set to 0.25 micrometers, and carrier concentration was set to  $1 \times 10^{17} \text{cm}^{-3}$ . On the luminous layer (104), GaN of p form was formed as an up cladding layer (105). Thickness set to 0.05 micrometers and carrier concentration was set to  $2 \times 10^{18} \text{cm}^{-3}$ . The laminated structure equipped with the double heterojunction by the crystal layer (103) (— (105)) directly deposited on these amorphous substrates was constituted. In analysis of a crystalline form [ / near the \*\*\*\* front face by reflection electron line diffraction (RHEED) ], the surface section of the GaN lower cladding layer (103) which is the first pass made to deposit on the front face of the quartz-glass substrate (101) which performed nitrogen plasma treatment was crystallized.

[0045] The anode plate electrode (107) which becomes the up cladding layer (105) which is equivalent to the outermost layer of a laminated structure from aluminum using a well-known photolithography technique was formed. The cathode electrode (108) which counters was formed on the lower cladding layer (103) which mesa etching was carried out [ cladding layer ] and made the circumference parts of an up cladding layer (105) and a luminous layer (104) expose.

[0046] The metal coat (109) which consists of aluminum for reflecting luminescence from a luminous layer (104) was made to put on the rear-face side of an amorphous quartz substrate (101) with vacuum deposition. The thickness of a metal coat (109) could be about 0.5 micrometers. Although the ingredient which constitutes the metal coat and electrode for reflection of luminescence was made the same in this example, even if it differs in the ingredient which does not specially restrict to such an ingredient configuration and constitutes an electrode and the metal coat for reflection, there is no inconvenience.

[0047] The semiconductor device (LED) which has the metal coat prepared in order to have the laminated structure which consists of an III-V group nitride semi-conductor layer equipped with the double heterojunction directly deposited on the front face of the amorphous substrate by which plasma treatment was carried out and to reflect luminescence in the rear-face side of an amorphous substrate by the above configuration was constituted. Luminescence was the blue which purple cut and the main wavelength was about 3850Å (Å). This luminescence was observed by impressing the direct current voltage of several volts (V) to forward [ above ] and the negative electrode, and the luminescence reinforcement of the non-mold article chip when setting forward current to 20mA became the about 62mm candela (mcd). Bringing increase of luminescence reinforcement to the rear-face side of an amorphous substrate ingredient with a metal coat was vividly shown from the obtained luminescence reinforcement being about 2.2 times the magnitude of LED which does not possess the metal coat which consisted of same double hetero laminated structures. If this result is optically compared with a transparent single crystal ingredient, even if it will be a cheap amorphous transparent material, by preparing the metal coat which reflects luminescence shows that luminescence to which reinforcement increased can be obtained.

[0048] (Example 3) The same laminated structure as an example 2 was directly prepared in the substrate front face which performed nitrogen plasma treatment of an example 2 by using amorphous fused-quartz glass as a substrate (101). The cross section of LED concerning this example is shown in drawing 6. each class which constitutes a laminated structure — MOCVD of ordinary pressure — by law, growth temperature was formed as 700 degrees C. The used substrate (101) was a round shape whose diameter is 50mm, and thickness was 150 micrometers.

[0049] Before obtaining a laminated structure, the straight-line-like slot (110) whose aperture width is 30 micrometers was periodically established in the rear face of a substrate (101) at intervals of 60 micrometers. That is, distance of the center to center of a slot was set to 60 micrometers. Although what is necessary is to \*\*\*\* the aperture width of a slot, and spacing of the center to center of a slot, and just to have set up, in order to share the cutting slot for the dicing for obtaining the chip of a slot (110) and the square whose one side is 360 micrometers, by this example, it considered as this value. This chip size is an example to the last. The cross-section configuration of a slot (110) was made into the hemicycle, and the depth of a slot (110) was set to 20 micrometers. The depth of this slot (110) became a little more than 13% of ratio to the thickness of a substrate (101). These slots (110) were formed by cutting which used the engine lathe.

[0050] On the amorphous quartz substrate (101) which formed the slot (110) in the rear face periodically, the same laminated structure as an example 2 was deposited directly. The electrode (107) (reaching (108)) as well

as a publication was formed in the above-mentioned example 2 by aluminum.

[0051] After forming a laminated structure and an electrode (107) (reaching (108)), vacuum deposition of the aluminum was carried out to the rear face of a substrate (101) on the whole surface, and the metal coat (109) which consists of aluminum for luminescence reflection was formed. Thickness of the metal coat (109) which carried out vacuum deposition was set to about 7 micrometers. In this example, after the metal coat for reflection passed through the process which forms a direct laminated structure on an amorphous substrate (101), it was prepared. this be because it be make to grow up at the temperature exceed 660 degrees C which be the melting point of aluminum of a metal coat ( 109 ) ingredient about above-mentioned each class which constitute a laminated structure like , so the fall of the surface area which a metal coat dissolve during growth , secede from the wall surface of a slot ( 110 ) , and show reflex action , i.e. , the decline in reflective effectiveness , will be produce if the metal of such the comparatively low melting point be make to put on the rear face of an amorphous substrate ( 101 ) beforehand .

[0052] Thus, it was admitted that luminescence reinforcement increased LED which equipped the obtained substrate with the metal coat for reflection as compared with LED of the conventional example. furthermore, the thing for which the metal coat for luminescence reflection is prepared in the field which increased especially the surface area of a publication in the example 3 -- only -- reflection -- public funds -- increase of the further reflectivity was attained rather than the case where a group is made to adhere to a substrate. Although particular difference was not made in the main wavelength of luminescence of LED obtained in the examples 2 and 3 when the example was shown, when comparing with the case of the aforementioned example 2, luminescence reinforcement reached the 1.3 times as many about 80mm candela (mcd) as this further.

[0053]

[Effect of the Invention] The plasma surface treatment with the gas containing nitrogen has the effectiveness to which single crystal-ization of the deposited growth phase is urged directly on an amorphous substrate. Moreover, it is effective in increasing the luminescence reinforcement as a component of LED by preparing a metal coat in the rear-face side of a substrate. If the surface area on the rear face of a substrate in which the metal coat for reflection is prepared is increased, the effectiveness which increases the reflectivity to the exterior of luminescence more will be demonstrated still more.

[0054] In addition, effectiveness is also demonstrated by that the effectiveness of this invention, especially the effectiveness that single crystal-ization is promoted by performing plasma treatment to the front face of an amorphous ingredient substrate obtain the so-called laminated structure of electron device applications, such as a hall device which comes to have heterojunctions, such as other semiconductor devices, for example, GaN/AlGaIn etc., and a field effect transistor, although this example explained LED as an example of the semiconductor device concerning this invention.

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[Translation done.]

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DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]

[Drawing 1] It is the cross section showing the example of the conventional blue LED chip.

[Drawing 2] It is the cross section of LED which it comes to fix to the plinth equipped with the reflecting mirror.

[Drawing 3] It is the cross section of the example of a laminated structure of the LED application concerning the example 1 of this invention.

[Drawing 4] It is the mimetic diagram of LED concerning the example 2 of this invention.

[Drawing 5] It is a cross section in alignment with broken-line A-A' shown in drawing 4 .

[Drawing 6] It is the cross section of LED concerning the example 3 of this invention.

[Description of Notations]

- (101) Substrate
- (102) Buffer coat
- (103) Lower cladding layer
- (104) Luminous layer
- (105) Up cladding layer
- (106) Contact layer
- (107) Anode plate electrode
- (108) Cathode electrode
- (109) Metal coat
- (110) Slot
- (111) Reflecting mirror
- (112) Chip
- (113) Stem
- (114) Enclosure resin
- (115) Connection
- (201) Silicon on sapphire

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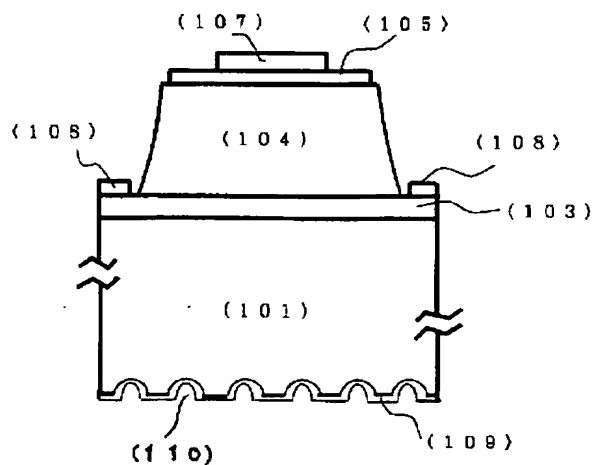
(54) 【発明の名称】 半導体装置及びその製造方法

(57) 【要約】

【目的】 非晶質を基板とする簡易な構成の発光強度が高いLED等の半導体装置を得る。

【構成】 窒素原子を含む気体からなるプラズマにより表面を処理した非晶質基板材料上に、III-V族窒化物半導体からなるヘテロ接合を含む積層構造を直接載置する。非晶質基板の裏面側に金属被膜を設ける。また、溝を形成した基板裏面に反射用途等の金属被膜を設ける。

【効果】 単結晶材料に比較すれば廉価な非晶質材料基板上に、結晶化されたIII-V族窒化物半導体を成長できる。また、基板材料への金属被膜の形成はLEDにおいては簡易な構成をもって発光強度の向上をもたらす。



## 【特許請求の範囲】

【請求項1】 Al、Ga若しくはInのうち少なくとも1種の第III族元素と、少なくとも窒素を含む第V族元素とからなるIII-V族窒化物半導体ヘテロ接合を、非晶質材料基板の表面上に直接堆積した積層構造から構成されてなる発光素子用の半導体装置。

【請求項2】 III-V族窒化物半導体ヘテロ接合を堆積した基板の表面とは反対側の、基板の裏面上に金属被膜が形成されてなる請求項1に記載の発光素子用の半導体装置。

【請求項3】 非晶質材料基板の裏面に複数の溝を設け、さらにその上に金属被膜を設けた請求項2に記載の発光素子用の半導体装置。

【請求項4】 非晶質材料基板を窒素原子を含むプラズマ雰囲気中に曝した後、該基板表面にAl、Ga若しくはInのうち少なくとも1種の第III族元素と、少なくとも窒素を含む第V族元素とからなるIII-V族窒化物半導体ヘテロ接合を堆積させることを特徴とする発光素子用半導体装置の製造方法。

## 【発明の詳細な説明】

## 【0001】

【産業上の利用分野】 III-V族窒化物半導体からなる半導体装置に係わり、特に高輝度の短波長可視発光ダイオード(LED)の発光強度の増大をもたらす材料の構成に関する。

## 【0002】

【従来の技術】 窒化ガリウム(GaN)や窒化アルミニウム(AlN)または窒化インジウム(InN)、或いはそれらの混晶等のIII-V族窒化物半導体は比較的高温でも動作する耐環境型の電界効果型トランジスタ

(M. Asif Khan他、Appl. Phys. Lett.、65(9)(1994)、1121。)やLED等の半導体装置の構成材料として用いられている。最近では、GaN等のIII-V族窒化物半導体の積層構造からなる青色や青緑色等の短い波長の可視光を発光する短波長可視LEDが構成されている(例えば真部 勝英、「豊田合成技報」、第35巻第4号(1993)、68頁)。

【0003】 III-V族窒化物半導体から構成されている従来のLEDチップの構造例を図1に示す。LEDチップを構成するための窒化物半導体各層は酸化アルミニウム(Al<sub>2</sub>O<sub>3</sub>)単結晶(サファイア)基板(201)上に設けられている(例えばH. M. Manasevit他、J. Electrochem. Soc.、118(1971)、1864)。従来から、基板としては、単結晶であるサファイアが使用されるのが通例となっている。

【0004】 単結晶であるサファイアが基板として用いられている理由の一つは、サファイアが青色等の短波長の光を透過するため発光が基板に吸収されず、外部への

発光の放出を防げないからである。LEDにあつては、外部へ効率良く発光を取り出すために発光波長に相当するエネルギーよりも高い禁止帯幅を有する材料から基板を構成するのが通例となっている。

【0005】 また、従来のLEDの構成要素であるGaNやAlN、或いはそれらの混晶であるIII-V族窒化物半導体の各層は約1000℃の高温で成長されている(M. Illegems、J. Cryst. Growth、13/14(1972)、360。)。III-V族窒化物半導体層の成長には、有機金属気相成長法(MOCVD、MOVPEやOMVPE法と称される。)やハロゲン化物を原料とする気相成長法(VPE法)等の成長方式に拘らず一般にこの様な高温が必要とされている。従って、高温の成長温度でも変質しない、融点が高い耐熱性のある材料を基板とする必要があつた。融点が成長温度を上回る約2040℃のサファイアを基板として利用する理由が此处にある。

【0006】 基板としてはこの他、単結晶の酸化ガリウム・ネオジウム(NdGaO<sub>3</sub>) (1994年秋季第55回応用物理学学会学術講演会講演予稿集No. 1、講演番号19p-MG-4、184頁)や同じく単結晶の酸化亜鉛(ZnO)が用いられている。ZnOの禁止帯幅は3.2eVと禁止帯幅が広く短波長の光を吸収せずに透過するため、且つAlGaInN等のIII-V族窒化物半導体混晶材料との格子の不整合度が小さいためIII-V族窒化物半導体の成長に適する基板として開示されている(特公平6-14564)。

【0007】 III-V族窒化物半導体層成長用の従来の基板材料は単結晶材料が利用されることが多い。サファイア等の単結晶は、一般にはアルミナの粉末或いは多結晶のサファイア塊等を原料として高温高压での環境下で合成される。単結晶合成工程を経た後、所望の形状に切削加工される。その後、表面を機械的或いは化学的に精密に研磨され、基板として供される。即ち、基板とする単結晶の材料を得るには多くの工程を経なければならず、従って単結晶材料は一般には高価である。

【0008】 単結晶材料を基板として使用する一般的な理由は単結晶の成長層を得るためである。即ち、単結晶基板上にエピタキシャル(epitaxial)成長した成長層は単結晶となるからである。単結晶成長層は同一の方位の結晶面から構築されているため、光学的或いは電気的な特性が画一化され、特性の揃ったLED等の素子を得るには都合が良い。むしろ、LEDは単結晶の膜から構成されることが要求される。

【0009】 しかし、AlN等のIII-V族窒化物半導体にあつては、単結晶ではない材料上に成長させた場合でも結晶化し、単結晶膜が得られることが知られている(赤崎勇、「光学」、第22巻第11号(1993)、670頁)。このことは単結晶のIII-V族窒化物半導体膜を得るに、一般的に高価な単結晶基板が敢えて必要

とされないことを意味する。即ち、単結晶化のため単結晶合成工程を要せず、一般的に単結晶の材料に比較すれば廉価である結晶性を持たない非晶質の材料が利用できることを示唆している。

【0010】過去にあっては、非晶質な材料としてパイレックスガラスを使用し、その上にIII-V族窒化物半導体の一種であるAlNの単層膜を形成した例が知られている(上村 揚一郎他、「応用物理」第40巻第5号(1971)、572頁)。また、導電性のガラス材料からなる電極上にAlN膜も設けた例がある(G. A. WOLFF他、Phys. Rev., 114 (5) (1959)、1262.)。しかし、従来に於ける例では、短い波長の可視光を発光する材料としてAl, Ga, In: N (x, y及びzは組成比を表し、 $x+y+z=1$ 、 $x>0$ である)が示されているが(特公平6-14564)混晶層等を発光層として備えたLED用途のヘテロ接合積層構造を、非晶質の材料上に直接設ける実施態様は例示されていない。

【0011】非晶質の材料を基板とする場合でも短い波長の光を透過する材料であれば外部へ発光が効率良く取り出せ、発光強度の増大が果たせる。透光性の材料の一面に、基板材料を透過してくる発光を反射する機能を有する金属被膜等を設ければ、エピタキシャル膜の結晶性の向上に依らずとも尚一層のLEDの高輝度化が簡便に図れる。また、発光部分をヘテロ接合で構成することにより、より高輝度化が図れる。

【0012】非晶質材料を石英ガラスとし、石英ガラスの一面上に金属導電膜を形成した後、Al, Ga<sub>1-x</sub>N ( $0 \leq x \leq 1$ )やInNエピタキシャル膜を堆積する成長方法も知られている。この場合は、III-V族窒化物半導体層を石英ガラス上に直接、堆積するのではなく、光学研磨を施した石英ガラス等の表面上に、一旦クロム(Cr)、ニッケル(Ni)、モリブデン(Mo)、金(Au)または白金(Pt)などの金属を導電膜として被着させて石英ガラス等の表面に導電性をもたせ、然る後、III-V族窒化物半導体層を成長させている(特公平5-86646)。しかし、この場合はヘテロ接合を含んでいない。また、この成長方法は成長層を石英ガラスの表面に形成した金属導電膜を介して形成することに依って、窒素空格子点の少ない高品質のAl, Ga<sub>1-x</sub>N ( $0 \leq x \leq 1$ )やInNのエピタキシャル膜の成長を目的としたものであって、エピタキシャル膜の結晶性の向上をもって高輝度の発光素子を作製するに有利とした方法にはかならない。即ち、石英ガラスの表面に設ける導電性膜は何も発光を反射させるための反射膜としての作用を果たすために設けられてはいなかった。

【0013】ましてや、公知例による石英ガラスの上に設けた金属導電膜を介してIII-V族化合物半導体層を成長させるに際しては、金属導電膜と金属アルミニウム等のターゲット材料との間に直流電圧を印加し、窒素ガ

スを含む雰囲気中で高周波スパッタリング法により、先ずAl, Ga<sub>1-x</sub>N ( $0 \leq x \leq 1$ )やInNのバッファ層を堆積する。その後、アンモニア(NH<sub>3</sub>)と第II族の有機金属を原料とする有機金属気相成長法によりバッファ層と同一の組成のAl, Ga<sub>1-x</sub>N ( $0 \leq x \leq 1$ )またはInNをエピタキシャル成長させる(特公平5-86646)。この成長方法に依れば、窒素空格子点の少ない高品質のAl, Ga<sub>1-x</sub>N ( $0 \leq x \leq 1$ )やInNのエピタキシャル膜が得られ、しいては高輝度の発光素子を作製できる利点があるとされるが、エピタキシャル膜を得るに煩雑な工程を必要としている。例えばエピタキシャル膜の成長工程にしてもスパッタリング法と有機金属気相成長法と2種の成長方法が必須となり、成長工程が複雑となり煩雑であるため、発光素子の製造価格の上昇を招きかねない。

【0014】例えばLEDの様な汎用素子にあっては、特に廉価であることが要求されるため、複雑な工程は好ましくない。非晶質材料からなる基板にあっては、基板上に直接III-V族窒化物半導体層を成長させても容易に単結晶膜は得られない。III-V族窒化物半導体層を堆積する非晶質材料の一面、即ち基板の表面にその上に堆積する成長層の単結晶化を促進できる簡易な表面処理が必要である。

【0015】発光素子の高輝度化はエピタキシャル成長膜の高品質化のみではなく、発光を反射する機能を有する構成とすれば簡易に高輝度化が達成される場合がある。例えば反射鏡を適当な位置に配置して外部への発光の放出を助長する従来法が知られている。この様な反射鏡を備えてなる従来のLEDの構成例を図2に示す。従来は高輝度化をもたらす反射鏡(111)はLEDのチップ(112)を固定するためのステム(台座器具)

(113)の一部に設けられている。従来に於いては、この様に発光を反射させるに特殊で構造が複雑となるステムが必要とされた。例えば、基板が透光性であれば、それを利用して基板の一部に反射作用を得ることを目的とした部材を被着すれば構造の簡素化が図れる。しかし、現在迄にこの様に高輝度化を果たすための発光を反射する作用を得る目的のための部材を有し、尚且つ簡素化された構成からなる高輝度のLEDは知られていない。

【0016】例えば図2に示す公知例とは異なり、透光性である石英ガラス基板のIII-V族窒化物半導体層の堆積を行う表面とは反対側の一面、即ち基板の裏面側に金属反射膜を設ければ発光のLEDの外部への反射強度を増大できる。反射膜を設ける基板の裏面の表面積を拡大する加工を施せば、反射強度は反射作用を有する反射膜の表面積の拡張に伴い増加するため更に増加する。表面積の増加をもたらす加工方法の一つに表面に凹凸状の溝を形成する方法がある。実際、表面側に溝を形成した(0001)面を有する六方晶系の基板上に、基板と

同様の六方晶系の結晶層を成長させる方法も公開されている（特開平5-36602）。しかし、従来は、溝は六方晶基板の表面側に形成されており、且つまた溝は基板と同じ結晶系の六方晶形の膜の表面状態を向上させる目的で設けられるもので、基板の一主面の表面積を拡張させるために溝が設けられているのではない。

#### 【0017】

【発明が解決しようとする課題】廉価なLEDを供給するには、非晶質材料を基板とするのが得策である。それには非晶質基板表面上に容易に単結晶膜を与える様な表面処理が必要である。更には、特殊なステムを必要とせずに発光を反射する作用を有する部材が基板と接触して設けられており、LEDからの発光の反射強度を増大させ結果としてLEDからの発光強度の増大がもたらされる簡易な構成があれば尚更都合が良い。しかし、現在に至る迄に短波長の可視LEDについて、電力消費が少なく、高輝度LEDを得るに必要なpn接合となすヘテロ接合系発光層を含む積層構造が、非晶質材料基板上に設けられた例は知られていない。または発光の反射強度の増大をもたらす構成を非晶質基板上に設けられた例は知られていない。この様な背景に鑑み廉価で且つ高輝度のLEDを供給するために、これらの従来の問題を新たな創意をもって解決するのが本発明の課題である。

#### 【0018】

【課題を解決するための手段】即ち、本発明は非晶質材料からなる基板を窒素原子を含む気体のプラズマ雰囲気中に曝して表面処理した後、Al、Ga若しくはInの少なくとも一つの第III族元素と第V族元素として少なくとも窒素を含むIII-V族窒化物半導体のヘテロ接合を備えた積層構造を、該非晶質材料基板の表面上に直接堆積することを特徴とするものである。また、III-V族窒化物半導体を直接堆積する非晶質基板の表面とは反対側の、対向する基板の裏面上に金属被膜が形成されてなる半導体装置を提供することを特徴とする。金属被膜は複数の溝を設けた非晶質基板の裏面上に設けられている半導体装置も提供する。

【0019】本発明では単結晶材料に比較すれば廉価な非晶質材料であり且つ透光性を有する材料を基板として利用する。非晶質材料とは、結晶学的に無定形（amorphous）か或いは部分的に結晶化した領域を持つミセル（miscel）構造を有する材料を指す。非晶質で且つ透光性の材料には、例えば非晶質ガラスや結晶化ガラスや石英ガラスなどが挙げられる。その他、透光性を有するAlNなどのセラミック材料もこれに該当する。GaNやAlN等の成膜温度が一般的に約1000℃と高温であるため、この様な高温でも軟化または融解せずに実用に耐える基板材料が望ましい。この点からすれば、比較的低温で軟化を起こす非晶質ガラス材料よりも石英ガラスやAlN等の透光性セラミック材料が都合

でも優れた透過性を有するため特に都合が良い。

【0020】本発明では、例えば石英ガラス基板等の非晶質基板材料の成長層の堆積を実施する一主面、即ち表面を窒素原子を少なくとも構成原子の一つとする分子を含む気体からなるプラズマ雰囲気中に曝し表面処理を行う。このプラズマ処理により、非晶質基板の表面に窒素原子を存在させることができる。基板表面の近傍に存在することとなった窒素原子は、表面上にIII-V族窒化物半導体層が成長する際に結晶の成長機構の面から見れば窒素のサイト（site）として働き、これにより単結晶膜の成長を容易にする効果がある。

【0021】本発明者らが鋭意検討した結果からは、窒素原子を少なくとも構成原子の一つとする分子として窒素ガスを使用し、80 Torrの真空環境に於いて、周波数が2.45 GHzのマイクロ波をもって窒素ガスを励起し、石英ガラス基板の表面を10分間処理すると、例えば常圧のMOCVD法により成長温度600℃で表層部が単結晶化されたGaN膜を得るのに十分なプラズマ表面処理となる。

【0022】基板表面を処理するプラズマは窒素ガスから生成させるに限らず、例えばアンモニア（NH<sub>3</sub>）や脂肪族、脂環式或いは芳香族アミン類や窒素原子を少なくとも一つの環の構成要素として含むピロール（Pyrrole）等の複素（ヘテロ環式）や窒素を含む置換基であるアミン基を含む化合物、アゾ基（-N=N-）を含む化合物等を利用して生成しても構わない。

【0023】基板表面の処理方法としては、プラズマを利用する方法以外に例えば窒素イオンを基板表面に注入する方法もある。しかし、本発明者らが検討を重ねた結果からは、プラズマ処理と同様の単結晶化についての効果を得るには、窒素イオンについて約300 KeVを越える加速エネルギーを必要とし、尚且つ10<sup>14</sup>から10<sup>15</sup> cm<sup>-2</sup> 或いはそれを越える多大なドーズ（dose）量を必要とする。ドーズ量が増大すると注入を終えるに至る時間が増加するため簡便な表面処理方法とはなり得なくなる。

【0024】本発明のいう非晶質の基板上に成長させるAl、Ga若しくはInの少なくとも一つのIII族元素と窒素とを含むIII-V族窒化物半導体の例にはGaN、AlN、InN、AlGaN、GaInN、AlInN、AlGaInN等がある。

【0025】また、Nに加える第V族元素としては、ヒ素（元素記号：As）やリン（元素記号：P）を含むIII-V族窒化物半導体も本発明に該当する。これには、GaNAs、GaN<sub>2</sub>P、AlNAs、AlNP、InNAs、InNP、AlGaNAs、AlGaNP、GaInNAs、GaInNP、AlInNAs、AlInNP、AlGaInNAs、AlGaInNP、GaN<sub>2</sub>PAs、AlNPAs、InNPAs、AlGaInNPAs等がある。



【0026】本発明では、これらのIII-V族窒化物半導体層の組合せからなるヘテロ接合積層構造を、上記のプラズマ処理を施した非晶質で且つ短波長の光を透過する材料からなる基板の表面上に直接積層する。従来例とは異なり基板上に直接、積層構造を堆積しても単結晶膜を得ることができる。単結晶膜を得ることができるのは基板表面上に上記のプラズマ処理を施したことによる。これより、従来の如く非晶質の石英ガラスやガラス上にAlGaInNまたはInNエピタキシャル膜を成長するに必要であった煩雑な成長工程を省略出来る利点がある。

【0027】非晶質基板上にIII-V族窒化物半導体層を直接堆積する際の成長方法には、特に制限はない。従来のMOCVD成長法やVPE成長法が利用できる。また、分子線エピタキシャル(MBE)法や化学ビームエピタキシャル(CBE)法等の成長方法もできる。MBE法には使用する原料の形態に依ってガスソース(GS)MBEや有機金属(MO)MBE等の方式が有るがいずれでも利用できる。III-V族窒化物半導体層を成長させるに当たってのGa、AlまたはIn或いはN原料についても制限はない。本発明は、非晶質の基板上に設けるIII-V族窒化物半導体層の窒素の空格子欠陥の低減による膜質の高品質化により発光強度の増大を果たすことを目的とはしていないため、従来例の如く複数の成長方法を必要とせず、よって半導体装置を作製するための積層構造を得るに際し、工程の簡略化が達成される。

【0028】ヘテロ接合は、前記したIII-V族窒化物半導体の例の中から、構成元素を異にする層或いは構成元素が同一であっても構成元素の組成を異にする層、即ち構成元素や組成を異にする異種(ヘテロ)の半導体を相互に接合させれば形成できる。例えばGaInNとGaInNPとのヘテロ接合は構成元素を異にする半導体層からなるヘテロ接合の例である。組成比を表すvとwの値を異にするInN<sub>1-v</sub>As<sub>v</sub>とInN<sub>1-w</sub>As<sub>w</sub>との接合は組成比を異にするヘテロ接合の例である。

【0029】ヘテロ接合を構成する層が2であれば接合界面(ヘテロ接合界面)は一つである。これを単一(シングル)ヘテロ接合と称す。3層よりヘテロ接合が構成されていればヘテロ接合界面の数は2となり二重(ダブル)ヘテロ接合と称される。ヘテロ接合界面の数が3であれば三重(トリプル)ヘテロ接合と称される場合もあるが、一般には多重ヘテロ接合と呼ばれる。積層構造にこれらのシングル、ダブルヘテロ接合や多重ヘテロ接合を含ませれば、本発明のいうヘテロ接合を備えた積層構造が形成される。

【0030】本発明では、光透過性の非晶質基板の一主面上に発光を反射させるための金属の被膜を設ける。金属被膜を設けるのはIII-V族窒化物半導体層を堆積する一主面、即ち基板の表面ではなく、基板の裏面上に設ける。この反射用被膜は金(元素記号: Au)やアルミ

ニウム(元素記号: Al)やクロム(元素記号: Cr)などの金属を真空蒸着法により基板の裏面側に被着させれば形成できる。短波長領域の発光に対する反射率の高さや廉価なLEDを得るための経済性等を勘案するとAlが最も適する。設ける金属被膜は単体からなる膜、例えばAlのみからなる膜であっても良いし、例えばAlとチタン(元素記号: Ti)の各層を重ねた2層構造の膜であっても構わない。単層或いは数層の金属被膜を設ける場合、各層の膜厚に特に制限はないが、1から10nm程度と極端に薄いと光が透過する確率も高くなるため好ましくない。100nmから5000nmの膜厚が実用上、適当である。例えば或る特定の波長の光の反射率を高めるために設計された膜厚を有するAl薄膜とTi薄膜とを多層に積層したいわゆる光干渉膜構造としても構わない。基板材料の一主面に反射作用を与える金属被膜を設ければ、従来例の如く反射鏡を別個にステム内に設ける必要もなく、簡易な構成をもってLEDの発光を外部へ反射でき、よってLEDからの発光強度の増大がもたらされる。勿論、従来の様な発光の反射鏡を備えたステムに本発明に係わる基板の裏面側に反射用金属被膜を備えた素子をマウントしても発光強度の増加を果たすという点では構わない。

【0031】反射光の強度は反射面として機能する面積が広い程増加する。本発明では、特に導電性を有するが故に基板の裏面側に反射用の金属被膜を設ける場合に於いて、基板の裏面側に溝を形成し基板の表面積を拡大し反射面積の増大を果たす。

【0032】溝は基板の裏面について公知のフォトリソグラフィ法によるパターンニング技術を利用しエッチング法等に依れば形成できる。例えば、非晶質の導電性ガラス材料の裏面を、一旦通常のフォトレジスト材料で被覆する。然る後、露光しフォトレジスト材料を感光させ所望するの溝の形状にパターンニングする。溝の部分に相当するフォトレジスト材料をレジスト剥離液等で除去し、基板材料の面を露呈させる。露呈させた領域に限り、エッチングを施し基板材料の一部を除去する。最終的に残存するフォトレジスト材料を剥離すれば、溝が形成された基板材料を得ることができる。溝は旋盤等の工作機械を利用して機械的な切削によっても形成できる。

【0033】表面積をより拡大するには、溝を格子状に形成すると良い。溝の断面の形状は限定がないが、断面を半円状とし、そこに金属反射被膜を設けるとほぼ全方位に発光を反射できる。また、基板の裏面に格子状の溝を形成すべく基板材料をエッチングし、除去するに際し、三角形の断面を与えるエッチング薬剤或いはエッチング条件を選択すると結果として三角錐状に穿孔され表面積の拡大をもたらす。基板に設ける溝の数量については特段の制限はない。但し、LEDの一般的なチップは一辺が300μmから450μmの方形であることから、このチップの形状内に少なくとも数本の溝が配置さ

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れるのが好ましい。

【0034】上記の様な溝を形成した後、発光を反射する機能を持つ反射膜とする金属被膜を形成すれば良い。金属被膜の形成方法としては真空蒸着法や塗布法が利用できる。塗布法では、例えば所望する金属粉或いは化合物等を含む液状の物質を溝を形成した基板の面に塗布し、然る後、加熱して固化させれば金属の被膜が形成できる。また、塗布法では液状の物質を利用するため溝等の段差を埋めるのに都合が良く、結果として平坦な表面の金属被膜が得られ易い利点がある。真空蒸着法やスパッタリング法等の物理的な堆積法では、数十 $\mu\text{m}$ を越える膜厚の被膜を得るのが容易でない場合がある。この様な場合は、溝の側面なり壁面を全体的に覆う程度に一旦被膜しておき、その被膜の上に然る後に鍍金（メッキ）法等により被膜の膜厚を増加させ、溝を埋め尽くす手段もある。但し、溝を金属被膜を構成する材料で完璧に埋め、取えて基板裏面を平坦化する絶対的な必要性はなく、溝の形状を故意に残存させても構わない。基板裏面側に金属被膜を構成する材料により不完全に埋め尽くされた凹凸上の段差を残した溝が存在すると、ステム材料

へ素子を固定するための接着固定剤の素子に対する接触面積の増加を招き頑固な固定を達成できるからである。【0035】基板に設ける溝の深さは、溝を深くするに伴い基板の表面積は拡大される傾向にあるため、溝を深くするほど発光の反射強度の増大を招くが、同時に基板が薄層化するため、基板の機械的強度が損なわれる。従って、基板に設ける溝の深さは基板の厚さに対して最深でも80%程度に止めておくのが好ましい。例えば厚さが300 $\mu\text{m}$ の基板については、溝の深さは最大でも240 $\mu\text{m}$ に止めておくのが良い。

#### 【0036】

【作用】非晶質基板表面の窒素原子を含む気体からなるプラズマ処理は、同表面上への単結晶III-V族窒化物半導体層の容易な形成をもたらし、従来の非晶質基板上へエピタキシャル膜成長工程の煩雑さを回避する。基板裏面に形成された金属被膜は、発光の外部への反射を増大させる。基板裏面に設ける溝は発光を反射する金属被膜の表面積を拡張し、反射強度を更に増加させる。

#### 【0037】

##### 【実施例】

（実施例1）本発明に係わる半導体装置用途の積層構造をMOCVD法により得る実施例を基に本発明を詳細に説明する。図3は本実施例に係わる積層構造の断面模式図である。基板（101）には絶縁性の非晶質AlNを用いた。このAlNは透光性を有していた。基板（101）の厚さは約300 $\mu\text{m}$ であった。

【0038】基板（101）を市販のドライエッチング装置の真空チャンバー内に載置した後、チャンバー内を真空度が約 $2 \times 10^{-5}$  100 Torrに到達する迄排気した。到達真空度がほぼ安定した時点でチャンバー内に

純度5Nの窒素ガスを導入し、チャンバー内の圧力を約100 Torrにした。然る後に、チャンバー内の平行平面電極に周波数が13.56MHzの高周波バイアスを印加し、窒素プラズマを発生させた。上記の基板（101）は平行に配置された平行平面電極の接地されている側の電極上に載置した。平行平面電極間に生成された窒素プラズマにより基板（101）の表面に窒素プラズマによる処理を施した。

【0039】窒素プラズマにより表面を処理したAlN基板（101）上に、直接n形のAlN<sub>0.05</sub>P<sub>0.95</sub>層を下部クラッド層（103）として堆積した。膜厚は約0.1 $\mu\text{m}$ であった。キャリア濃度は約 $1 \times 10^{18} \text{ cm}^{-3}$ とした。この層（103）はトリメチルガリウム（ $(\text{CH}_3)_3\text{Ga}$ ）／トリメチルアルミニウム（ $(\text{CH}_3)_3\text{Al}$ ）／ホスフィン（ $\text{PH}_3$ ）／水素（ $\text{H}_2$ ）反応系による常圧MOCVD法により、温度750℃で成長させた。次に $\text{PH}_3$ の体積濃度を10%となる様に高純度水素で希釈された $\text{PH}_3$ と $\text{H}_2$ との混合ガスと（ $\text{CH}_3$ ）<sub>3</sub>GaとのMOCVD反応系への供給を停止し、代わりにシクロペンタジエニルインジウム（ $\text{C}_5\text{H}_5\text{In}$ ）とアンモニア（ $\text{NH}_3$ ）を反応系に供給し、p形のGa<sub>0.4</sub>In<sub>0.6</sub>N層を発光層（104）として堆積した。温度70℃に保持した $\text{C}_5\text{H}_5\text{In}$ と $\text{NH}_3$ の反応系内への添加流量は170cc/分と11cc/分に各々設定した。膜厚は約0.1 $\mu\text{m}$ とした。キャリア濃度は約 $1 \times 10^{17} \text{ cm}^{-3}$ とした。

【0040】これにより、窒素プラズマにより表面処理された非晶質AlNからなる基板（101）の表面に、従来の如く金属被膜を介さずに直接堆積されたAlN<sub>0.05</sub>P<sub>0.95</sub>からなる下部クラッド層（103）とGa<sub>0.4</sub>In<sub>0.6</sub>Nからなる発光層（104）とのヘテロ接合を形成した。窒素プラズマにより処理された基板（101）表面の上に堆積した成長層（（103）及び（104））は、通常のX線回折法による回折パターンから、いずれも単結晶化された膜であることが判った。

【0041】次に、発光層（104）上にp形のGa<sub>0.98</sub>As<sub>0.02</sub>からなる上部クラッド層（105）を積層した。膜厚は0.3 $\mu\text{m}$ とし、キャリア濃度は約 $2 \times 10^{18} \text{ cm}^{-3}$ とした。As源としては水素希釈されたアルシン（体積濃度10%）－高純度水素（体積濃度90%）の混合ガスを使用した。Ga源とした（ $\text{CH}_3$ ）<sub>3</sub>Gaは恒温槽により温度0℃に保持し毎分30ccの流量をもって反応系に供給した。アルシン（ $\text{AsH}_3$ ）は35cc/分の流量とした。

【0042】以上の構成により、AlN<sub>0.05</sub>P<sub>0.95</sub>層（103）とGa<sub>0.4</sub>In<sub>0.6</sub>N層（104）とのヘテロ接合とGa<sub>0.4</sub>In<sub>0.6</sub>N層（104）とGa<sub>0.98</sub>As<sub>0.02</sub>（105）とのヘテロ接合とからなるダブルヘテロ接合を備えたLED用途の積層構造を非晶質AlN基板（101）上に直接、堆積することにより構成し

た。このダブルヘテロ接合積層構造を使用して短波長LEDを作成した。このLEDは青緑色を帯びた青色の発光が観測され、その中心の発光波長は約4720オングストローム(Å)であった。発光強度についての従来例との比較では、本実施例に係わるLEDは、従来のLEDと遜色ない強度を与えるのが認められた。ここで、従来のLEDとはカドミウム(Cd)や亜鉛(Zn)等の不純物を添加した、Inの組成比率が0.2程度のGaInNを発光層とする深緑色の発光をもたらすLEDを指す。一方、発光スペクトルの半値幅は約340オングストローム(Å)であり、これに関しては上記の従来のLEDに比較すれば約1/2(従来のLEDに於ける発光スペクトルの半値幅は約700オングストロームである。)と格別に顕著な改善が達成されるものとなった。半値幅が縮小した一因として、本発明では表面を窒素プラズマ処理した基板を使用することにより、その上に堆積するヘテロ接合層内の窒素の空孔(vacancy)濃度の減少がもたらされたものと判断された。

【0043】(実施例2)ナトリウム、カリウム、リチウム等のアルカリ金属類の総含有量が5重量ppm以下の非晶質石英ガラスを基板(101)として使用した。図4に本実施例に係わるLEDの構造の平面模式図を、図5に図4の破線A-A'に沿う断面模式図を示す。石英ガラス基板(101)の表面を実施例1に記載の方法に則り、窒素プラズマによる表面処理を施した。プラズマ処理時の真空度等の条件は実施例1とほぼ同一としたが、プラズマ生成時のパワーは210Wと増大させた。実施例1で基板として使用した非晶質のAlNは、そもそも窒素原子を構成元素として含んでいるが、石英ガラスは二酸化珪素(SiO<sub>2</sub>)を主成分とし窒素原子を構成元素として含有しないため、石英ガラス基板の表面に効率良く窒素のサイトを形成するためにプラズマパワーを増大させた。

【0044】プラズマ処理を施した石英ガラス基板(101)の表面に、直接上記の常圧MOCVD法によりn形のGaN層を下部クラッド層(103)として堆積した。膜厚は約0.1μmとした。キャリア濃度は約 $1 \times 10^{18} \text{ cm}^{-3}$ とした。次に、p形のGa<sub>0.88</sub>In<sub>0.12</sub>N層を発光層(104)として堆積した。発光層(104)の膜厚は0.25μmとし、キャリア濃度は $1 \times 10^{17} \text{ cm}^{-3}$ とした。発光層(104)上にはp形のGaNを上部クラッド層(105)として形成した。膜厚は0.05μmとし、キャリア濃度は $2 \times 10^{18} \text{ cm}^{-3}$ とした。これらの非晶質基板上に直接堆積された結晶層((103)~(105))によりダブルヘテロ接合を備えた積層構造を構成した。反射電子線回折(RHEED)による極く表面近傍に於ける結晶形態に関する分析では、窒素プラズマ処理を施した石英ガラス基板(101)の表面に堆積させた第一層であるGaN下部クラッド層(103)の表層部は結晶化していた。

【0045】積層構造の最表層にあたる上部クラッド層(105)に公知のフォトリソグラフィ技術を利用してAlからなる陽極電極(107)を形成した。対向する陰極電極(108)は上部クラッド層(105)及び発光層(104)の周辺部分をメサエッチングして露呈させた下部クラッド層(103)上に形成した。

【0046】非晶質な石英基板(101)の裏面側には、発光層(104)からの発光を反射するためのAlからなる金属被膜(109)を真空蒸着により被着させた。金属被膜(109)の膜厚は約0.5μmとした。本実施例では、発光の反射用の金属被膜と電極を構成する材料を同一としたが、別段このような材料構成に限ることはなく、電極と反射用の金属被膜とを構成する材料を異にしても差し支えない。

【0047】以上の構成により、プラズマ処理された非晶質基板の表面上に直接堆積されたダブルヘテロ接合を備えたIII-V族窒化物半導体層からなる積層構造を有し、且つ非晶質基板の裏面側に発光を反射する目的で設けられた金属被膜とを有する半導体装置(LED)を構成した。発光は紫色がかった青色であって、その中心波長は約3850オングストローム(Å)であった。この発光は上記の正及び負電極に数ボルト(V)の直流電圧を印加することにより観測され、順方向電流を20mAとした時の非モールド品チップの発光強度は約62ミリカンデラ(mcd)に達した。得られた発光強度は、同様のダブルヘテロ積層構造から構成された金属被膜を具備しないLEDの約2.2倍の大きさであることから、非晶質の基板材料の裏面側に金属被膜によって、発光強度の増大をもたらすことが如実に示された。この結果は光学的に透明な単結晶材料に比較すれば廉価な非晶質透明材料であっても、発光を反射する金属被膜を設けることによって強度が増大した発光を得ることができることを示している。

【0048】(実施例3)非晶質の熔融石英ガラスを基板(101)として、実施例2と同様の積層構造を実施例2の窒素プラズマ処理を施した基板表面に直接設けた。図6に本実施例に係わるLEDの断面模式図を示す。積層構造を構成する各層は常圧のMOCVD法により、成長温度を700℃として形成した。使用した基板(101)は直径が50mmの円形であり、厚みは150μmであった。

【0049】積層構造を得る前に、基板(101)の裏面には開口幅が30μmの直線状の溝(110)を60μmの間隔で周期的に設けた。即ち、溝の中心間の距離を60μmとした。溝の開口幅や溝の中心間の間隔は適宜、設定すれば良いが、本実施例では溝(110)と一辺が360μmの正方形のチップを得るためのダイシング用の切削溝とを共用するためこの値とした。このチップサイズはあくまでも一例である。溝(110)の断面形状は半円形とし、溝(110)の深さは20μmとし

た。この溝(110)の深さは基板(101)の厚さに対して13%強の比率となった。これらの溝(110)は旋盤を使用した切削加工により形成した。

【0050】裏面に溝(110)を周期的に形成した非晶質石英基板(101)の上には、実施例2と同様の積層構造を直接堆積した。電極((107)及び(108))も上記実施例2に記載と同様にAlにより形成した。

【0051】積層構造及び電極((107)及び(108))を形成した後、基板(101)の裏面に全面にAlを真空蒸着し、発光反射用のAlからなる金属被膜(109)を形成した。真空蒸着した金属被膜(109)の厚さは約7 $\mu$ mとした。本実施例では、反射用の金属被膜は非晶質基板(101)上に直接積層構造を形成するプロセスを経た後設けた。これは、上記した様に積層構造を構成する各層を、金属被膜(109)材料のAlの融点である660℃を上回る温度で成長させているため、予め非晶質基板(101)の裏面にこのような比較的低い融点の金属を被着させておくと成長中に金属被膜が溶解し、溝(110)の壁面から離脱し反射作用を示す表面積の低下、即ち反射効率の低下を生ずるからである。

【0052】この様にして得られた基板に反射用の金属被膜を備えたLEDは、従来例のLEDに比較し、発光強度が増加するのが認められた。更に、特に実施例3に記載の表面積を増大させた面に発光反射用の金属被膜を設けることにより、単に、反射用金属を基板に付着させた場合よりも更なる反射強度の増大が達成された。具体例を示せば、実施例2及び3で得られたLEDの発光の中心波長には然したる相違はないものの、前記の実施例2の場合に比較すれば発光強度は更にその1.3倍の約80ミリカンデラ(mcd)に到達した。

【0053】

【発明の効果】窒素を含有する気体によるプラズマ表面処理は非晶質基板上に直接、堆積された成長層の単結晶化を促す効果がある。また、基板の裏面側に金属被膜を設けることによってLEDの素子としての発光強度を増大させる効果がある。反射用の金属被膜を設ける基板裏面の表面積を増大させれば尚更、発光の外部への反射強

度をより増大される効果が発揮される。

【0054】尚、本実施例では本発明に係わる半導体装置の一例としてLEDについて説明したが、本発明の効果、特に非晶質材料基板の表面にプラズマ処理を施すことにより単結晶化が促進される効果は他の半導体装置、例えばGaN/AlGaN等のヘテロ接合を備えてなるホール素子、電界効果型トランジスタ等のいわゆる電子デバイス用途の積層構造を得るにも効果が発揮される。

【図面の簡単な説明】

【図1】従来の青色LEDチップの例を示す断面模式図である。

【図2】反射鏡を備えた台座に固定されてなるLEDの断面模式図である。

【図3】本発明の実施例1に係わるLED用途の積層構造例の断面模式図である。

【図4】本発明の実施例2に係わるLEDの平面模式図である。

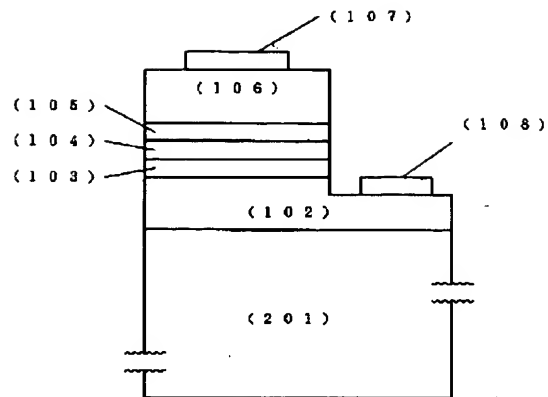
【図5】図4に示した破線A-A'に沿った断面模式図である。

【図6】本発明の実施例3に係わるLEDの断面模式図である。

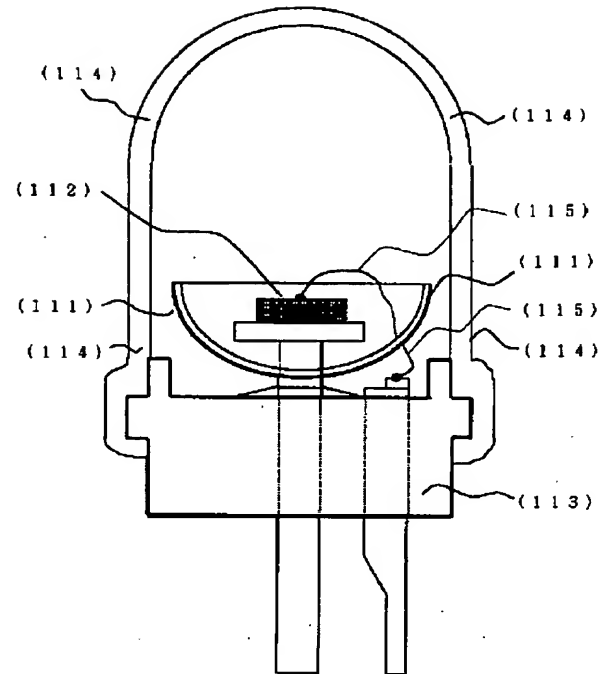
【符号の説明】

- (101) 基板
- (102) 緩衝層
- (103) 下部クラッド層
- (104) 発光層
- (105) 上部クラッド層
- (106) コンタクト層
- (107) 陽極電極
- (108) 陰極電極
- (109) 金属被膜
- (110) 溝
- (111) 反射鏡
- (112) チップ
- (113) ステム
- (114) 外囲樹脂
- (115) 結線
- (201) サファイア基板

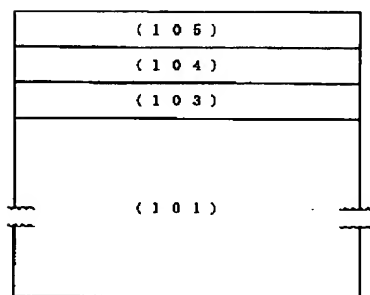
【図1】



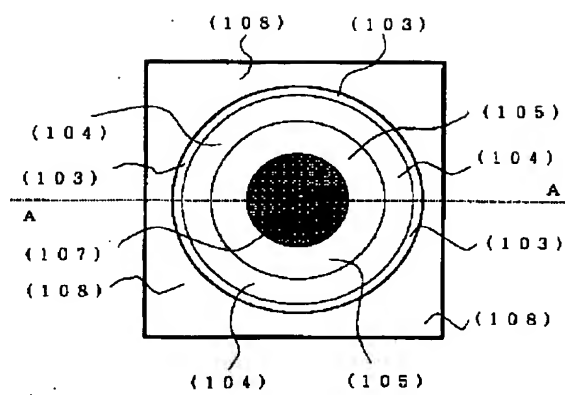
【図2】



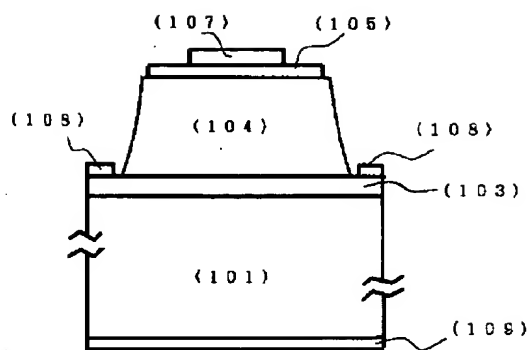
【図3】



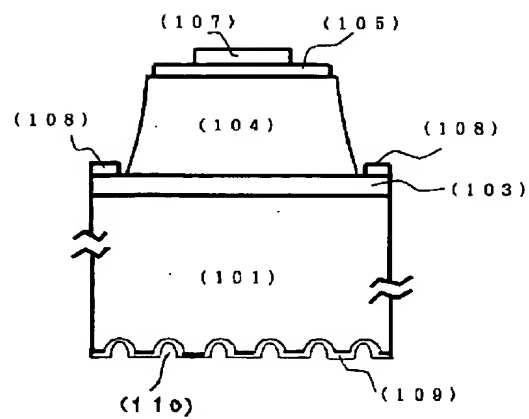
【図4】



【図5】



【図6】



フロントページの続き

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